Published in final edited form as:

J Am Soc Hypertens. 2016 March ; 10(3): 224–234.e17. doi:10.1016/j.jash.2015.12.013.

Studies Comparing Ambulatory Blood Pressure and Home Blood Pressure on Cardiovascular Disease and Mortality Outcomes: A Systematic Review

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Abstract

Ambulatory blood pressure monitoring (ABPM) is more commonly recommended for assessing out-of-clinic blood pressure than home blood pressure monitoring (HBPM). We conducted a systematic review to examine whether ABPM or HBPM is more strongly associated with cardiovascular disease events and/or mortality. Of 1,007 abstracts published through July 20, 2015, nine articles, reporting results from seven cohorts, were identified. After adjustment for blood pressure on HBPM, blood pressure on ABPM was associated with an increased risk of outcomes in two of four cohorts for systolic blood pressure and two of three cohorts for diastolic blood pressure. After adjustment for blood pressure on ABPM, systolic blood pressure on HBPM was associated with outcomes in zero of three cohorts; an association was present in one of two cohorts for diastolic blood pressure on HBPM. There is a lack of strong empiric evidence supporting ABPM or HBPM over the other approach for predicting cardiovascular events or mortality.

Keywords

hypertension; ambulatory blood pressure monitoring; home blood pressure monitoring

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Conflicts of Interest: Dr. Paul Muntner received an institutional grant from Amgen Inc. unrelated to the topic of the current manuscript. Dr. Raymond Townsend reports grant support from Fukuda Denshi unrelated to the current manuscript. There are no other potential conflicts of interest.

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Introduction

To identify patients with hypertension and monitor their blood pressure while taking antihypertensive medication, most guidelines and scientific statements recommend measuring blood pressure in the clinic setting.¹⁻⁵ This recommendation is supported by extensive data, which have demonstrated that elevated clinic blood pressure is associated with increased cardiovascular disease (CVD) risk, and lowering of clinic blood pressure with antihypertensive medication is associated with a proportional reduction in risk.¹⁻⁵

Data have been published demonstrating that blood pressure may differ substantially when measured outside of versus in the clinic setting.⁶⁻⁸ There are two well-accepted approaches for measuring blood pressure outside of the clinic setting: ambulatory blood pressure monitoring (ABPM) and home blood pressure monitoring (HBPM). Higher blood pressure on ABPM and HBPM has each been shown to be associated with an increased risk of CVD events and mortality independent of clinic blood pressure.^{9, 10}

Recent guidelines including from the US Preventive Services Task Force (USPSTF)^{4, 5, 11-14} have recommended the assessment of out-of-clinic blood pressure using ABPM over HBPM. However, there is controversy about which method, ABPM or HBPM, is superior for measuring out-of-clinic blood pressure and assessing blood pressure-related CVD risk.¹⁵⁻¹⁷ We conducted a systematic review of published studies to provide an objective assessment of whether blood pressure from ABPM or from HBPM is more consistently associated with CVD events and/or mortality.

Methods

Search Strategy and Selection Criteria

Articles were included if they met the following criteria: (1) included participants aged 18 years; (2) conducted both ABPM and HBPM; and (3) had follow-up for CVD events and/or mortality. We excluded articles that only reported results from cross-sectional analyses, review articles, letters to the editor, commentaries, editorials, or meeting abstracts. There was no restriction on language, sample size or duration of follow-up. When two articles reported the results from the same cohort, the one with more person-years of follow-up or more outcomes (either number or type of outcomes) was included. However, if two articles from the same cohort reported different ABPM or HBPM phenotypes (e.g., one study reported mean blood pressure and another study reported white coat hypertension) or outcomes (e.g., one study reported CVD and another study reported all-cause mortality) or modeled the same phenotype differently (e.g., daytime systolic blood pressure modeled as a continuous variable in one article and modeled in categories in a separate article) on the same population, both were included.

The following databases were searched through July 20, 2015: MEDLINE, EMBASE and CENTRAL. The MEDLINE search strategy is described in the online Data Supplement (Supplemental Methods). Terms for the other databases were adapted accordingly. To supplement the database searches, a PubMed related articles search and a cited reference search through ISI Web of Science were conducted using the included articles identified

from the first set of results. A manual search was also performed using the reference lists from the included articles and review articles produced by the electronic database searches.

Two investigators (D.S. and M.A.) independently reviewed all identified articles for eligibility using the above criteria. The title and abstract of identified articles were reviewed, and those deemed ineligible were excluded. The full text for the remainder of articles were retrieved and reviewed. Discrepancies on whether to include a study were resolved by discussion with a third investigator (P.M.).

Data Extraction

Data were independently abstracted from all articles by two investigators (D.S. and M.A.) using a standardized instrument. Study characteristics (publication year, cohort name, first author, sample size, population characteristics, location including city and country of origin, outcomes, and follow-up period), BP measurement methodology (device, number and frequency of readings, and duration of monitoring), and results (e.g., hazard ratios [HRs]) from the most fully adjusted models were abstracted for the study population. The quality of data abstraction was monitored by comparing the forms of the data abstractors. Discrepancies in data abstraction were resolved by discussion with a third investigator (P.M.), as needed. The articles varied by participant and sample characteristics, blood pressure measurement technique, and outcomes. Therefore, the results of the studies meeting the inclusion criteria were not pooled due to substantial clinical and methodological heterogeneity.

Results

Identification of Articles

The original search identified 545 abstracts (Figure 1). After review of the title and abstract, 520 abstracts were excluded. Of the 25 full-text articles retrieved, 17 were excluded, leaving eight original articles. An additional three potentially relevant articles were identified from a manual search of the reference lists from these articles. An additional 462 abstracts were identified in a supplemental search of other sources (reference lists, related articles search, citations). No articles were selected from this supplemental search. Of the 11 potentially relevant articles, one article¹⁸ was excluded based on duplicate results discovered upon data extraction, and another article¹⁹ was excluded because it reported results using fewer outcomes than another article from the same cohort.²⁰ In total, nine articles²⁰⁻²⁸ met the inclusion/exclusion criteria for data abstraction. Of these articles, six reported data from separate cohorts,^{20-24, 28} and three reported data from the Pressioni Arteriose Monitorate e Loro Associazioni (PAMELA) cohort.²⁵⁻²⁷ In total, data were available from seven cohorts.

Study Characteristics

The earliest²⁴ and most recent²⁸ identified articles were published in 1996 and 2014 respectively (Table 1). Sample sizes ranged from 150 to 2,051 participants. The articles included participants from the general population,²⁴⁻²⁷ a clinic population sample,²³ participants with either chronic kidney disease (CKD) or ESRD,²⁰⁻²² and a mixed population of participants from the general population and clinical practice.²⁸ Outcomes

included all-cause mortality;^{20, 21, 24-27} CVD death;^{20, 25-27} a composite of stroke, myocardial infarction, and CVD death;²³ a composite of stroke, myocardial infarction and all-cause mortality;²² and a composite of CVD mortality, myocardial infarction, stroke, heart failure hospitalization, and coronary revascularization.²⁸

Methodology for Blood Pressure Measurement

For ABPM, a Spacelabs 90202 or 90207 device was used in five cohorts,^{20-23, 25-27} a Colins 360 device was used in one cohort,²⁴ and a Suntech Accutacker II device was used in one cohort²⁸ (Table 2). Duration of ABPM ranged from 24 to 44 hours. The interval between readings ranged from 15 to 30 minutes during the daytime period, and 20 to 30 minutes during the nighttime period. For HBPM, a Philips HP 5331 device;²⁵⁻²⁷ an Omron 410C or 701C;²⁴ an Omron 412C;²² an Omron 705CP;²⁰ an Omron 705CP or 790IT;²¹ an Omron 705C;²⁸ and manual assessment using a mercury sphygmomanometer by an investigator²³ were each used in one cohort. The number of HBPM readings that were obtained each day ranged from 1 to 4 and the duration of HBPM ranged from 1 day to 4 weeks. In each study, clinic blood pressure was obtained manually using a sphygmomanometer and/or a semi-automated/automated device.

Systolic Blood Pressure and Outcomes

Table 3 shows summary results for the analysis of daytime systolic blood pressure on ABPM and HBPM, modeled as a continuous variable, in five cohorts.^{20, 22, 23, 27, 28} If daytime blood pressure was not reported, or multivariable models, which adjusted for blood pressure on HBPM, also included blood pressure on ABPM over the entire monitoring period (e.g., 24 hours or 44 hours) or nighttime blood pressure, then these ABPM results are included. Detailed results for the extracted data are provided in Supplemental Table 1. In all five cohorts, average systolic blood pressure measured by ABPM was associated with increased risk of CVD events and/or mortality in models that did not adjust for average systolic blood pressure on HBPM (upper panel, Table 3). Average systolic blood pressure (24-hour or nighttime) on ABPM was associated with outcomes in the two^{23, 28} of three^{23, 27, 28} cohorts that reported results after adjustment for average systolic blood pressure on HBPM (lower panel, Table 3). In models that did not adjust for average systolic blood pressure on ABPM, average systolic blood pressure measured by HBPM was associated with increased risk of CVD events and/or mortality in four of five cohorts (upper panel, Table 3).^{22, 23, 27, 28} Of the four cohorts reporting an association between HBPM and outcomes,^{22, 23, 27, 28} two cohorts^{23, 28} conducted additional analyses adjusting for mean blood pressure on ABPM (lower panel, Table 3). The associations between average systolic blood pressure measured by HBPM and outcomes were attenuated and not statistically significant after adjustment for mean blood pressure on ABPM.^{23, 28}

Systolic blood pressure (defined as quartiles, quintiles, or in two levels) on ABPM was associated with increased risk of CVD events and/or mortality in models that did not adjust for systolic blood pressure on HBPM in five of five cohorts (Supplemental Table 2).^{20-22, 24, 27} Three^{21, 22, 27} of five cohorts showed that systolic blood pressure on HBPM, modeled in categories, to be associated with increased risk of CVD events and/or mortality in models that did not adjust for systolic blood pressure on ABPM. Only one cohort²¹

included both systolic blood pressure on ABPM and HBPM in the same adjusted model, and found that the associations of blood pressure on ABPM and HBPM with outcomes were not statistically significant.

Diastolic Blood Pressure and Outcomes

In five cohorts, average diastolic blood pressure on ABPM, modeled as a continuous variable, was associated with increased risk of CVD events and/or mortality in models that did not adjust for average diastolic blood pressure on HBPM (upper panel, Table 4). Detailed results are provided in Supplemental Table 3. Three^{23, 27, 28} cohorts conducted additional analyses adjusting for mean blood pressure on HBPM, and the associations between average diastolic blood pressure (24-hour and nighttime) on ABPM and outcomes was statistically significant in two cohorts (lower panel, Table 4).^{23, 28} In models that did not adjust for average diastolic blood pressure on ABPM, average diastolic blood pressure measured by HBPM was associated with increased risk of CVD events and/or mortality in four cohorts (upper panel, Table 4).^{20, 23, 27, 28} Diastolic blood pressure measured by HBPM was associated with outcomes in one²³ of two cohorts^{23, 28} that adjusted for mean blood pressure on ABPM (lower panel, Table 4).

Diastolic blood pressure, modeled as a categorical variable, was reported in three cohorts^{22, 24, 27} (Supplemental Table 4). In these cohorts, diastolic blood pressure on ABPM was associated with the risk of CVD events and/or mortality in models that did not adjust for diastolic blood pressure on HBPM. Two cohorts^{24, 27} showed that diastolic blood pressure on HBPM was associated with increased risk of CVD events and/or mortality in models that did not adjust for diastolic blood pressure on ABPM. None of these cohorts adjusted for diastolic blood pressure on ABPM and HBPM simultaneously.

An overall summary of the associations between systolic and diastolic blood pressure measured by ABPM and HBPM on CVD and/or all-cause mortality is shown in Table 5.

Categories Defined by Hypertension Status in the Clinic, on ABPM and/or on HBPM

Three articles reported on categories, defined by the presence of hypertension, defined using both systolic and diastolic blood pressure, in the clinic, on ABPM and/or on HBPM (Supplemental Table 5).^{23, 25, 26} Two cohorts^{23, 26} reported associations of categories, defined by the cross-classification of hypertension status in the clinic and on ABPM, with outcomes. One cohort²⁶ reported associations of categories, defined by the cross-classification of hypertension status in the clinic and on HBPM, and categories, defined by the cross-classification of hypertension status on ABPM and HBPM, with outcomes. One cohort²⁵ reported associations of categories, defined by the classification of hypertension status in the clinic, on ABPM, and on HBPM, with outcomes. No cohort examined whether outcomes differ between individuals with hypertension on ABPM but not on HBPM and individuals with hypertension on HBPM but not on ABPM.

Discussion

In the current systematic review, we identified seven cohorts that conducted both ABPM and HBPM, and examined their associations with CVD events and/or mortality. Blood

pressure on ABPM and HBPM were each associated with an increased risk of CVD events and/or mortality when considered separately. In two of four cohorts, systolic blood pressure, and in two of three cohorts, diastolic blood pressure on ABPM, were associated with an increased risk of CVD events and/or mortality after adjusting for systolic blood pressure and diastolic blood pressure, respectively, on HBPM. In contrast, no cohort reported systolic blood pressure on HBPM to be associated with outcomes after adjusting for systolic blood pressure on ABPM, and one of two cohorts reported that diastolic blood pressure on HBPM was associated with outcomes after adjusting for diastolic blood pressure on ABPM.

Prior systematic reviews and/or meta-analyses have examined the relative value of ABPM and HBPM for diagnosing hypertension,^{29, 30} and predicting target organ damage.³¹ In these studies, ABPM was assumed to be the gold standard or was not directly compared with HBPM in predicting clinical outcomes. To our knowledge, no prior systematic review of studies that directly compared blood pressure from ABPM versus HBPM on CVD events and/or mortality has been conducted. By focusing only on the studies that contained both ABPM and HBPM, our systematic review was able to compare ABPM to HBPM for predicting CVD events and/or mortality.

From the published data, it cannot be concluded that blood pressure from ABPM has a stronger association with CVD events and/or mortality compared with blood pressure measured on HBPM. The number of articles that examined the independent associations of ABPM and HBPM on CVD events and/or mortality was small. Only two cohorts were exclusively population-based: one from Japan (Ohasama)²⁴ and one from Italy (PAMELA).²⁵⁻²⁷ The associations reported were also not consistent with some articles demonstrating lower blood pressure on ABPM, defined as a categorical variable, to be associated with an increased risk for outcomes.^{21, 22, 24} Further, in two cohorts,^{23, 25-27} HBPM was performed for only a single day. Published guidelines and position papers recommended that HBPM be performed for a minimum of 3 consecutive days and a preferred period of 7 consecutive days.^{5, 32, 33} Thus, an optimal assessment of blood pressure from HBPM may not have been obtained. Finally, in one article,²³ HBPM was conducted manually by a study investigator rather than by self-measurement using a semi-automatic or automatic device, highlighting possible prognostic differences between HBPM obtained by another person vs. self-measurement of blood pressure at home.

Currently, there is ongoing debate about which method, ABPM or HBPM, is better for the assessment of out-of-clinic blood pressure. Conceptually, blood pressure on ABPM is different than blood pressure on HBPM. ABPM assesses daytime and nighttime blood pressure during routine daily activities typically over a single 24-hour period inside and outside the home, whereas HBPM assesses blood pressure during specific times of the day and night over a longer period of time (i.e. days to weeks) while an individual is seated and resting at home. There is only moderate correlation between blood pressure on ABPM and HBPM.³⁴ Some argue that more evidence exists demonstrating an association of blood pressure on ABPM with CVD events and/or mortality.¹⁶ Further, unlike HBPM, ABPM can assess the diurnal pattern of blood pressure, particularly blood pressure at night.¹³ In the current study, only one cohort²³ reported that nighttime systolic and diastolic BP was associated with outcomes after adjusting for BP on HBPM. Proponents of HBPM argue that

in addition to home blood pressure being associated with outcomes, HBPM devices are more widely available than ABPM devices.^{15, 32} Further, it has been proposed that HBPM is associated with greater patient acceptability and tolerability, better reproducibility, and improved antihypertensive medication adherence.^{32, 35, 36}

Currently, guidelines, scientific statements, and position papers most commonly recommend ABPM to exclude white coat hypertension, defined as having elevated clinic blood pressure but non-elevated out-of-clinic blood pressure.^{1, 4, 5, 11-14, 37} Other indications for ABPM include the monitoring of antihypertensive medication efficacy in treated hypertensive patients who have elevated clinic blood pressure in order to determine blood pressure control over the course of the day. Less common recommendations for ABPM include the assessment of masked hypertension, treated masked hypertension, diurnal blood pressure patterns, and 24-hour blood pressure variability. HBPM is not recommended as often as ABPM. HBPM is most commonly recommended to diagnose white coat hypertension or assess treatment resistant hypertension.^{1, 4, 5, 13, 14, 37} In 2011, based on cost-effectiveness data, the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom recommended that ABPM be performed to confirm the diagnosis of hypertension in individuals presenting with clinic hypertension.⁴ HBPM was recommended when ABPM was not well tolerated by the patient. In 2015, the USPSTF recommended out-of-clinic blood pressure measurement be performed to confirm the diagnosis of hypertension in individuals presenting with clinic hypertension.^{11, 12} The USPSTF recommended that ABPM be the reference standard for confirming the diagnosis of hypertension and that HBPM is an alternative if ABPM is not available. In the current study, systolic and diastolic blood pressure on ABPM were associated with outcomes after adjusting for HBPM in only two cohorts, and diastolic blood pressure on HBPM was associated with outcomes after adjusting for ABPM in only a single cohort.²³ Until further outcome studies are conducted that compare HBPM to ABPM, it will remain unclear which method is superior for predicting CVD outcomes.

In conjunction with clinic blood pressure, both ABPM and HBPM can each be used to assess for white coat hypertension and masked hypertension, defined as having non-elevated clinic blood pressure and elevated out-of-clinic blood pressure.¹³ However, prior studies have shown only 42% of individuals who have white coat hypertension on ABPM or HBPM have this diagnosis on both modalities.²⁵ A low concordance for masked hypertension on ABPM and HBPM has also been reported.³⁸ In our systematic review, no article reported whether white coat hypertension and masked hypertension have different associations with CVD events and/or mortality when assessed using ABPM and, separately, HBPM.

There are several possible study limitations. Due to the substantial heterogeneity across the articles, pooling data and conducting a formal meta-analysis was not possible. Articles adjusted for different covariables, which could have contributed to the divergent results that were observed across articles in our systematic review. Methodological factors that influence blood pressure measurement (i.e., different devices, different number of readings, etc.) may have also affected the associations of blood pressure on ABPM and HBPM with outcomes that were reported in the included articles.

In conclusion, the results of the current systematic review demonstrate an association of blood pressure on ABPM and, separately, on HBPM with an increased risk of CVD events and/or mortality. However, a firm conclusion of whether ABPM or HBPM is superior for assessing CVD risk cannot be made due to the small number of cohorts that included both ABPM and HBPM, and the existence of important study limitations including heterogeneity in sample characteristics, blood pressure measurement technique, and outcomes. Therefore, there is no strong empiric evidence to support the guidelines that recommend ABPM over HBPM for the diagnosis and management of hypertension.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Sources of Funding: This work was supported by the National Institutes of Health (HL047540, HL117323, HL117323-02S2, K24-HL125704) from the National Heart, Lung, and Blood Institute, Bethesda, MD. The funding source had no role in the study design, collection, analysis, interpretation, or drafting of the manuscript or in the decision to submit the manuscript for publication.

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Highlights

- Ambulatory and home blood pressure are each associated with clinical outcomes.
- Few outcome studies included both blood pressure measures in the same study.
- No strong data support the superiority of either blood pressure for outcomes.

Figure 1. Flow diagram of article selection for the systematic review

Table 1
Characteristics of included articles, which were comprised of cohorts from the general population (top panel), clinical practice (second panel), CKD/ESRD populations (third panel), and from a mixed population (bottom panel)

General population samples						
Publication Year	First Author	Sample Size with ABPM and HBPM	Treatment Status	Location	Outcomes	Follow-up Period
1996	Imai et al. ²⁴ (Ohasama)	1,057 had clinic BP; 893 had ABPM; 1,226 had HBPM (did not report sample size that had all three measurements)	Untreated	Ohasama, Japan	All-cause mortality	4.98 years (mean) for clinic BP analysis; 4.53 years (mean) for ambulatory BP analysis; 5.19 years (mean) for home BP analysis
2005	Sega et al. ^{*27} (PAMELA)	2,051	Untreated and treated	Monza, Italy	All-cause mortality; CVD death	131 months (mean)
2006	Mancia et al. ^{*26} (PAMELA)	2,051	Untreated and treated	Monza, Italy	All-cause mortality; CVD death	148 months (mean)
2013	Mancia et al. ^{*25} (PAMELA)	1,589	Untreated and treated	Monza, Italy	All-cause mortality; CVD death	16 years (mean)
Clinical population samples						
Publication Year	First Author	Sample Size with ABPM and HBPM	Treatment Status	Location	Outcomes	Follow-up Period
2005	Fagard et al. ²³	391	Untreated and treated	Flanders, Belgium	Composite of stroke, myocardial infarction, and CVD death	10.9 years (median); 0.04-13.0 years (range)
CKD/ESRD populations						
Publication Year	First Author	Sample Size with ABPM and HBPM	Treatment Status	Location	Outcomes	Follow-up Period
2006	Agarwal et al. ²²	210 CKD patients not on HD	Untreated and treated	Indianapolis, Indiana, United States	Composite of stroke, myocardial infarction, and all-cause mortality	3.4 years (median) 2.8-3.7 years (IQR)
2007	Alborzi et al. ²⁰	150 ESRD patients on HD	Untreated and treated	Indianapolis, Indiana, United States	All-cause mortality; CVD death	24 months (median); 16-32 months (IQR)
2010	Agarwal et al. ²¹	323 ESRD patients on HD	Untreated and treated	Indianapolis, Indiana, United States	All-cause mortality	29 months (median); 16-48 months (IQR)
Combined general population and clinical practice samples						
Publication Year	First Author	Sample Size with ABPM and HBPM	Treatment Status	Location	Outcomes	Follow-up Period
2014	Niiranen et al. ²⁸	502 (combined 264 from the general population and 238	Untreated and treated	Turku, Finland	Composite of CVD mortality, myocardial infarction, stroke,	16.1 years (mean); 16.7 years (median)

General population samples						
Publication Year	First Author	Sample Size with ABPM and HBPM	Treatment Status	Location	Outcomes	Follow-up Period
		hypertensive patients from clinical practice hypertensive patients from clinical practice)			heart failure hospitalization, percutaneous coronary intervention, and coronary artery bypass graft surgery	

* These articles analyzed data from the same cohort (PAMELA).

ABPM = ambulatory blood pressure monitoring

BP = blood pressure

CKD = chronic kidney disease

CVD = cardiovascular disease

ESRD = end-stage renal disease

HBPM = home blood pressure monitoring

IQR = interquartile range

HD = hemodialysis

PAMELA = Pressioni Arteriose Monitorate e Loro Associazioni

Table 2

Methodology for measurement of BP within included articles, which were comprised of cohorts from the general population (top panel), clinical practice (second panel), CKD/ESRD populations (third panel), and from a mixed population (bottom panel)

General population samples				
Year	First Author	Ambulatory BP Measurement Method	Home BP Measurement Method	Clinic BP Measurement Method
1996	Imai et al. ²⁴	Colin ABPM 630 device; 24-hour recording; every 30 minutes during daytime and nighttime periods	Omron HEM 410C & HEM 701C; daily for 4 weeks; 1 morning reading; excluded participants who did not have at least 3 readings	Automated device: USM-700F device; 2 readings
2005	Sega et al. ^{*27}	Spacelabs 90207 device; 24-hour recording; every 20 minutes during daytime and nighttime periods	Philips HP 5531 semi-automatic device; on 1 day; 1 morning and 1 evening reading	Manual using mercury sphygmomanometer; 3 readings daily for 2 consecutive days
2006	Mancia et al. ^{*26}	Spacelabs 90207 device; 24-hour recording; every 20 minutes during daytime and nighttime periods	Philips HP 5531 semi-automatic device; on 1 day; 1 morning and 1 evening reading	Manual using mercury sphygmomanometer; 3 readings daily for 2 consecutive days (first day reading used for analysis)
2013	Mancia et al. ^{*25}	Spacelabs 90207 device; 24-hour recording; every 20 minutes during daytime and nighttime periods	Philips HP 5531 semi-automatic device; on 1 day; 1 morning and 1 evening reading	Manual using mercury sphygmomanometer; 3 readings daily for 2 consecutive days (first day reading used for analysis)
Clinical population samples				
Year	First Author	Ambulatory BP Measurement Method	Home BP Measurement Method	Clinic BP Measurement Method
2005	Fagard et al. ²³	Spacelabs 90202 or 90207 device; 24-hour recording; every 15 minutes during the daytime and 30 minutes during the nighttime periods	Manual using mercury sphygmomanometer (by same investigator who measured blood pressure in the clinic); 3 readings	Manual using mercury sphygmomanometer; 3 readings
CKD/ESRD populations				
Year	First Author	Ambulatory BP Measurement Method	Home BP Measurement Method	Clinic BP Measurement Method
2006	Agarwal et al. ²²	Spacelabs 90207 device; 24-hour recording; every 20 minutes during the daytime and 30 minutes during the nighttime periods	Omron HEM 412C; daily for 7 days; 1 morning reading, 1 afternoon reading, 1 evening reading (3 readings per day); 1 st day readings excluded; excluded participants who did not have at least 10 readings	Automated device: DINAMAP 1846SX ("routine blood pressure"); 2 readings over 2 days (1 reading per day) Semi-automated: Omron 412C ("standardized blood pressure"); 3 readings during one visit
2007	Alborzi et al. ²⁰	Spacelabs 90207 device; 44-hour recording; every 20 minutes during the daytime and 30 minutes during the nighttime periods	Omron HEM 705CP; daily for 7 days; 1 morning reading, 1 afternoon reading, 1 evening reading (3 readings per day)	Manual using sphygmomanometer ("routine blood pressure"); 6 predialysis readings and 6 postdialysis readings over 2 weeks Semi-automated: Omron HEM 907 ("standardized blood pressure"); 6 predialysis readings and 6 postdialysis readings over 2 weeks
2010	Agarwal et al. ²¹	Spacelabs 90207 device; 44-hour recording; every 20 minutes during the daytime and 30 minutes during the nighttime periods	Omron HEM 705CP or HEM 790IT; daily for 7 days; 1 morning reading, 1 afternoon reading, 1 evening reading (3 readings per day)	Manual using sphygmomanometer ("routine blood pressure"); 6 predialysis readings and 6 postdialysis readings over 2 weeks
Combined general population and clinical practice samples				
Year	First Author	Ambulatory BP Measurement Method	Home BP Measurement Method	Clinic BP Measurement Method

General population samples				
Year	First Author	Ambulatory BP Measurement Method	Home BP Measurement Method	Clinic BP Measurement Method
2014	Niiranen et al. ²⁸	Suntech Accutracker II; 24-hour recording; every 15 minutes during the daytime and 30 minutes during the nighttime periods	Omron HEM 705C; daily for 7 days; 2 morning readings, 2 evening readings (4 readings per day)	Manual using mercury sphygmomanometer; 2 readings $\times$ 4 over 3 weeks

* These articles analyzed data from the same cohort (PAMELA).

BP = blood pressure
CKD = chronic kidney disease
ESRD = end-stage renal disease

Table 3
Summary results reported for continuous analysis of SBP measured by ABPM and HBPM and outcomes

Article	Outcome	Ambulatory SBP			Home SBP	
		HR (95% CI) *	Measure	HR adjusted for HBPM?	HR (95% CI) *	HR adjusted for ABPM?
ABPM not adjusted for HBPM and HBPM not adjusted for ABPM						
Sega et al. 2005 ²⁷	All-cause mortality CVD death	1.36 (1.24-1.51) 1.61 (1.38-1.89)	Daytime Daytime	No No	1.40 (1.32-1.48) 1.56 (1.42-1.72)	No No
Alborzi et al. 2007 ²⁰	All-cause mortality CVD death	1.18 (1.04-1.35) 1.19 (1.01-1.41)	44-hour 44-hour	No No	1.14 (1.00-1.31) 1.18 (0.99-1.41)	No No
Fagard et al. 2005 ²³	Composite of stroke, MI, and CVD death	1.27 (1.05-1.54)	Daytime	No	1.17 (1.02-1.33)	No
Agarwal et al. 2006 ²²	Composite of stroke, MI, and all-cause mortality	1.21 (1.03-1.42)	Daytime	No	1.23 (1.09-1.39)	No
Niiranen et al. 2014 ²⁸	Composite of CVD mortality, MI, stroke, HF hospitalization, PCI, and CABG	1.37 (1.20-1.57) 1.38 (1.21-1.58)	Daytime 24-hour	No No	1.33 (1.14-1.55)	No
ABPM adjusted for HBPM and HBPM adjusted for ABPM						
Sega et al. 2005 ²⁷	CVD death	NR (NR); p=0.370 [†]	Daytime	Yes [†]		NR [†]
Fagard et al. 2005 ²³	Composite of stroke, MI, and CVD death	1.13 (0.93-1.38) 1.16 (1.01-1.34)	Daytime Nighttime	Yes Yes	1.11 (0.98-1.25) 1.10 (0.98-1.24)	Yes (daytime) Yes (nighttime)
Niiranen et al. 2014 ²⁸	Composite of CVD mortality, MI, stroke, HF hospitalization, PCI, and CABG	1.55 (1.18-2.04)	24-hour	Yes	0.91 (0.64-1.31)	Yes (24-hour)

Bolded items are statistically significant (p<0.05). Results for ABPM primarily focus on daytime BP. Results for BP over the entire monitoring period (e.g., 24 hours or 44 hours) or nighttime BP are included if daytime BP was not reported or the adjusted models included BP on HBPM.

* For every 10 mmHg increase in SBP. The B coefficients (SE) in the study by Sega et al.²⁷, and the various HRs (95% CI) from the studies by Alborzi et al.²⁰, Fagard et al.²³, Agarwal et al.²², and Niiranen et al.²⁸ were converted to HRs (95% CI) for every 10 mmHg increase in SBP.

[†] In a model that did not include home SBP, an increase in daytime SBP on ABPM was associated with an increased risk of CVD death. In a model that did not include daytime SBP, an increase in home SBP was associated with an increased risk of CVD death. The addition of daytime SBP to a model that contained clinic SBP and home SBP did not improve the goodness of fit for the risk of CVD death. The improvement in the goodness of fit was not reported for the addition of home SBP to a model that contained clinic SBP and daytime SBP.

BP = blood pressure

CABG = coronary artery bypass graft

CI = confidence interval

CVD = cardiovascular disease

HF = heart failure

HR = hazard ratio

MI = myocardial infarction

NR = not reported

PCI = percutaneous coronary intervention

SBP = systolic blood pressure

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Table 4
Summary results reported for continuous analysis of DBP measured by ABPM and HBPM and outcomes

Article	Outcome	Ambulatory DBP			Home DBP	
		HR (95% CI)*	Measure	HR adjusted for HBPM?	HR (95% CI)*	HR adjusted for ABPM?
ABPM not adjusted for HBPM and HBPM not adjusted for ABPM						
Sega et al. 2005 ²⁷	All-cause mortality CVD death	1.11 (1.02-1.22) 1.19 (1.02-1.40)	Daytime Daytime	No No	1.22 (1.15-1.3) 1.3 (1.18-1.44)	No No
Alborzi et al. 2007 ²⁰	All-cause mortality CVD death	1.15 (1.03-1.28) 1.15 (1.00-1.32)	44-hour 44-hour	No No	1.13 (1.01-1.27) 1.20 (1.03-1.4)	No No
Fagard et al. 2005 ²³	Composite of stroke, MI, and CVD death	1.22 (1.05-1.42)	Daytime	No	1.24 (1.11-1.4)	No
Agarwal et al. 2006 ²²	Composite of stroke, MI, and all-cause mortality	0.87 (0.76-1)	24-hour	No	0.91 (0.81-1.03)	No
Niiranen et al. 2014 ²⁸	Composite of CVD mortality, MI, stroke, HF hospitalization, PCI, and CABG	1.25 (1.10-1.41) 1.27 (1.12-1.44)	Daytime 24-hour	No No	1.15 (1.02-1.29)	No
ABPM adjusted for HBPM and HBPM adjusted for ABPM						
Sega et al. 2005 ²⁷	CVD death	NR (NR) [†]	Daytime	Yes [†]		NR [†]
Fagard et al. 2005 ²³	Composite of stroke, MI, and CVD death	1.05 (0.90-1.22) 1.14 (1.01-1.28)	Daytime Nighttime	Yes Yes	1.17 (1.04-1.32) 1.17 (1.04-1.31)	Yes (daytime) Yes (nighttime)
Niiranen et al. 2014 ²⁸	Composite of CVD mortality, MI, stroke, HF hospitalization, PCI, and CABG	1.58 (1.22-2.04)	24-hour	Yes	0.95 (0.74-1.21)	Yes (24-hour)

Bolded items are statistically significant (p<0.05). Results for ABPM primarily focus on daytime BP. Results for BP over the entire monitoring period (e.g., 24 hours or 44 hours) or nighttime BP are included if daytime BP was not reported or the adjusted models included BP on HBPM.

* For every 5 mmHg increase in DBP. The B coefficients (SE) in the study by Sega et al.²⁷, and the various HRs (95% CI) from the studies by Alborzi et al.²⁰, Fagard et al.²³, Agarwal et al.²², and Niiranen et al.²⁸ were converted to HRs (95% CI) for every 5 mmHg increase in DBP.

[†] In a model that did not include home DBP, an increase in daytime DBP was associated with an increased risk of CVD death. In a model that did not include daytime DBP, an increase in home DBP was associated with an increased risk of CVD death. For the separate analyses that examined the improvement in goodness of fit (see corresponding analyses for SBP in Table 3 above), the study reported that “similar results were obtained for DBP values (data not shown).”

BP = blood pressure
CABG = coronary artery bypass graft
CI = confidence interval
CVD = cardiovascular disease
DBP = diastolic blood pressure
HF = heart failure
HR = hazard ratio
MI = myocardial infarction
PCI = percutaneous coronary intervention

Table 5
Summary of articles reporting BP (as a continuous or categorical variable) measured by ABPM and HBPM on outcomes

Article	Outcome	Ambulatory BP*		Home BP	
		Associated with outcomes not adjusting for home BP?	Associated with outcomes adjusting for home BP?	Associated with outcomes not adjusting for ambulatory BP?	Associated with outcomes adjusting for ambulatory BP?
Systolic BP modeled as a continuous variable					
Sega et al. 2005 ²⁷	All-cause mortality CVD death	Yes Yes	NR No [†]	Yes Yes	NR NR
Fagard et al. 2005 ²³	Composite outcome [‡]	Yes	Yes	Yes	No
Agarwal et al. 2006 ²²	Composite outcome [§]	Yes	NR	Yes	NR
Alborzi et al. 2007 ²⁰	All-cause mortality CVD death	Yes Yes	NR NR	No No	NR NR
Niiranen et al. 2014 ²⁸	Composite outcome	Yes	Yes	Yes	No
Systolic BP modeled as a categorical variable					
Imai et al. 1996 ²⁴	All-cause mortality	Yes	NR	No	NR
Sega et al. 2005 ²⁷	CVD death	Yes	NR	Yes	NR
Agarwal et al. 2006 ²²	Composite outcome [§]	Yes	NR	Yes	NR
Alborzi et al. 2007 ²⁰	All-cause mortality CVD death	Yes No	NR NR	No No	NR NR
Agarwal et al. 2010 ²¹	All-cause mortality	Yes	No	Yes	No
Diastolic BP modeled as a continuous variable					
Sega et al. 2005 ²⁷	All-cause mortality CVD death	Yes Yes	NR No ^{††}	Yes Yes	NR NR
Fagard et al. 2005 ²³	Composite outcome [‡]	Yes	Yes	Yes	Yes
Agarwal et al. 2006 ²²	Composite outcome [§]	Yes	NR	No	NR
Alborzi et al. 2007 ²⁰	All-cause mortality CVD death	Yes No	NR NR	Yes Yes	NR NR
Niiranen et al. 2014 ²⁸	Composite outcome	Yes	Yes	Yes	No
Diastolic BP modeled as a categorical variable					
Imai et al. 1996 ²⁴	All-cause mortality	Yes	NR	Yes	NR

Article	Outcome	Ambulatory BP*		Home BP	
		Associated with outcomes not adjusting for home BP?	Associated with outcomes adjusting for home BP?	Associated with outcomes not adjusting for ambulatory BP?	Associated with outcomes adjusting for ambulatory BP?
Sega et al. 2005 ²⁷	CVD death	Yes	NR	Yes	NR
Agarwal et al. 2006 ²²	Composite outcome [§]	Yes	NR	No	NR

Yes (in bold) = at least one analysis was significant (p<0.05). No = no analysis was significant (p<0.05).

* Any component of 24-hour ABPM (daytime, nighttime, 24-hour)

[†]The addition of 24-hour SBP, daytime SBP, and separately nighttime SBP to a model that contained clinic SBP and home SBP did not improve the goodness of fit for the risk of CVD death.

[‡]Stroke, myocardial infarction, and CVD death.

[§]Stroke, myocardial infarction, and all-cause mortality.

//CVD mortality, myocardial infarction, stroke, heart failure hospitalization, percutaneous coronary intervention, and coronary artery bypass graft surgery.

[¶]In a model that did not include home SBP, increasing quartiles of ambulatory SBP (44-hour, awake, and sleep) was associated with increased all-cause mortality; and in a model that did not include ambulatory SBP, increasing quartiles of home SBP (quartile 2 only) was associated with increased all-cause mortality. In a separate analysis, this study noted that for the prediction of all-cause mortality, “models containing ambulatory and home BP showed similar fits by the likelihood ratio test”, suggesting that neither outperformed the other out-of-clinic measure.

^{††}For the analyses that examined the improvement in goodness of fit (see corresponding analyses for SBP above[¶]), the study reported that “similar results were obtained for DBP values (data not shown).”

BP = blood pressure

CVD = cardiovascular disease

NR = not reported